Chapter 4

Laboratory Fittings

There are many good reasons why laboratory fittings of standard design should be used. The scientist can indicate his requirements more quickly and the architect has fewer drawings and specifications to prepare; the savings in cost of manufacture and installation are considerable and the units can be re-used if it becomes necessary to alter the layout of the laboratory.

In Australia, all bench units are timber. In the United States of America, where there is a very large market and the labour costs are high, most are steel; this material is more adaptable to mass production and the units are demountable. They are fire-proof and termite-proof and the maximum precautions are taken to ensure that they will resist corrosion and chemical attack. Before assembly, the steel components are cleaned and treated in a phosphate bath; they are then coated with epoxy resin and heat cured. However, there are still some laboratory people in the USA who are prepared to pay a little extra for timber units.

In 1946 CSIRO designed a range of standard laboratory fittings, and many thousands of these have been used by the Organization and by government departments and private industry. One local manufacturer specialises in the production of the bench units and, in my opinion, they are at least equal to any I have seen overseas. Despite the fact that these units are available commercially, some people still prefer their own design. This results in increased cost, especially when more expensive timbers and unnecessary elaboration are specified.

BENCHES

The various types of CSIRO standard bench units are shown in Figs. 6, 7 and 8. The width of the larger units is 4 ft 9 in which was determined by the width at the end of a peninsular bench, *i.e.* 5 ft less 1½ in bench top projection on both sides; incidentally, this size is about the maximum which can be conveniently man-handled on the job. To provide flexibility in planning, it was also found necessary to have a 2 ft 3 in wide unit. However, the wider unit is more economical because obviously there is almost as much labour involved in making a 2 ft 3 in unit as in making one 4 ft 9 in—for example, in 1971 the cost of a 2 ft 3 in Type H cupboard unit is $60 compared with $88 for a 4 ft 9 in Type E cupboard unit, and a 2 ft 3 in Type J drawer unit is $75 as against $107 for a 4 ft 9 in Type D1 drawer and cupboard unit. This means that, especially in a large job, considerable savings can be effected by restricting the use of the smaller units to a minimum.

Details of the construction of a typical CSIRO unit are shown in Fig. 9. The ends, divisions and doors are framed and they have a honey-comb core, sheeted both sides with plywood; doors and drawers are fitted flush. Some manufacturers are now using particle board, veneered both sides. This involves less labour, but higher material cost; the price of the finished product therefore is about the same. For best quality work, framed construction is still recommended.

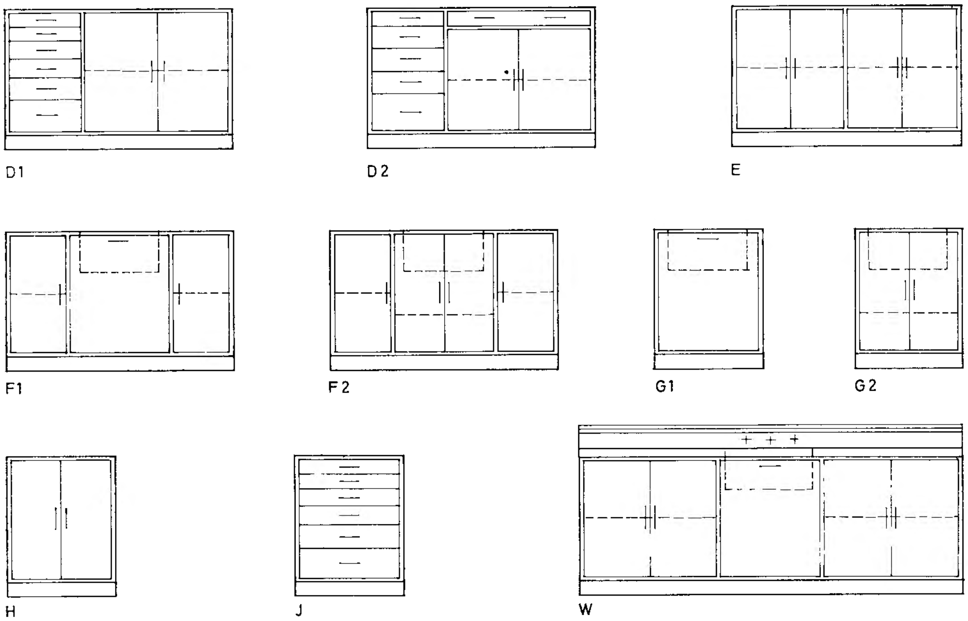

FIGURE 6 *CSIRO standard laboratory bench units.*

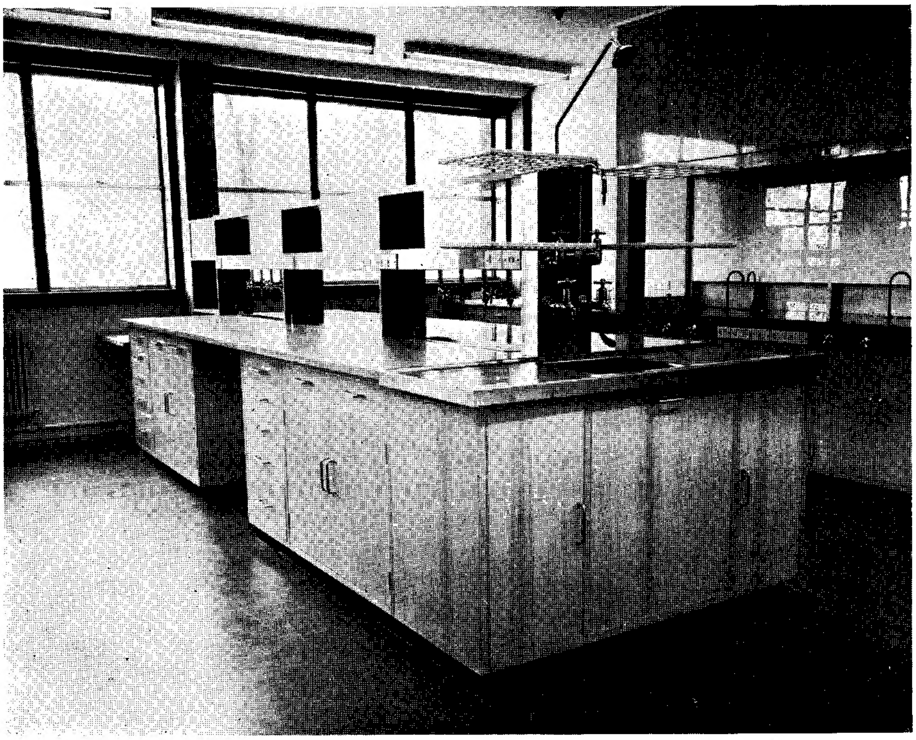

FIGURE 7 *View of a peninsular bench in a standard three-module laboratory; CSIRO Division of Land Research, Canberra, ACT. This layout is shown in Figure* 1.

By using a knee space with a combination of bench units, any specific length of bench can be obtained; furthermore, any on-site variation of length between partitions can easily be overcome by altering the width of the knee space. Also, a knee space makes it more comfortable to sit at a bench, it provides a convenient place for some equipment and it reduces the number of bench units, thus saving money. The width of a knee space should be no less than 2 ft, and no more than

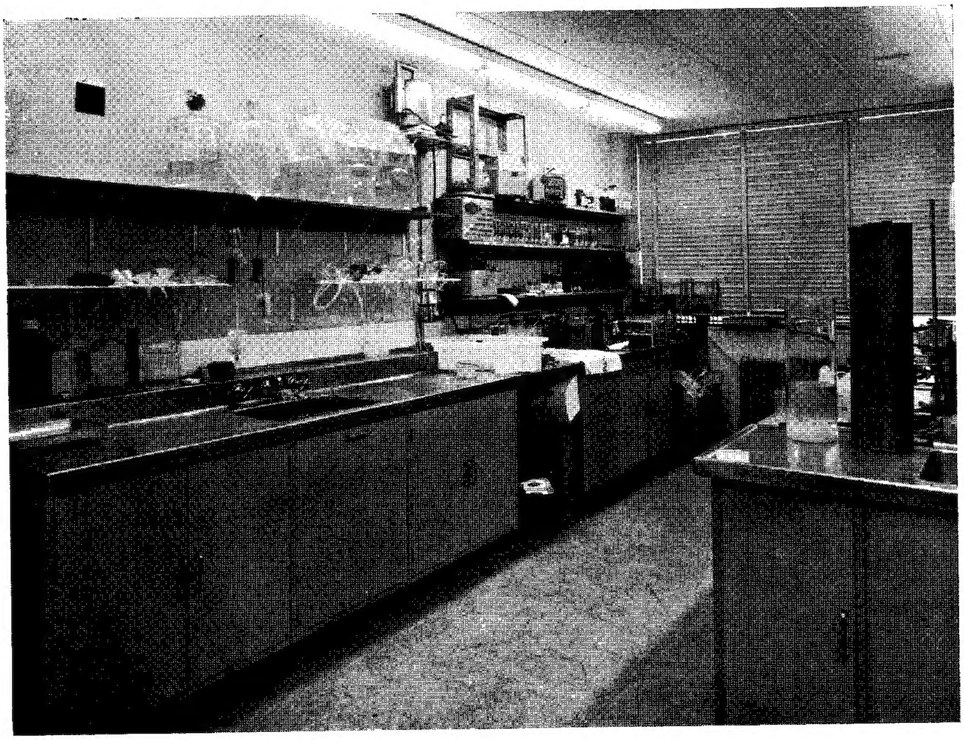

FIGURE 8 *View of a wall bench; Biochemistry Laboratory, CSIRO Division of Plant Industry, Canberra, ACT.*

3 ft 6 in—about the maximum span of an unsupported bench top. If it is necessary for it to be wider, a front rail should be used up to 5 ft and a leg if it is wider still.

Benches are installed by the simplest method, *i.e.* the tops are supported by the drawer and cupboard units. When the service pipes have been installed and the service strip fixed above them, the units are placed in position (packed and scribed if necessary) and the tops are fitted. A slip joint is provided in the bench top at the junction of the service strip and the unit beneath; for wall bench installations where there are not many services, this joint is sometimes omitted and the one-piece top extends back to the wall. The service duct is 15 in. in peninsular benches and $7\frac{1}{2}$ in. in wall benches; access is obtained by removing screw-fixed panels at the backs of knee spaces and cupboard units.

In an effort to increase the flexibility of benches and accessibility of pipes, other methods of installation have been used; the trouble is that some of them give less and cost more. One method is to have the bench top supported on a steel frame and the units either fitted with casters or just

pushed underneath; in a laboratory where the bench units must be mobile, or where very few units are required, this offers the best solution. Another idea is to have the bench units suspended from a steel frame and clear of the floor. Admittedly this gives a lighter and more modern appearance, but, if the space beneath the unit is sufficient to allow the floor to be properly cleaned, the reduction in the storage capacity of the unit is considerable—at little or no reduction in cost.

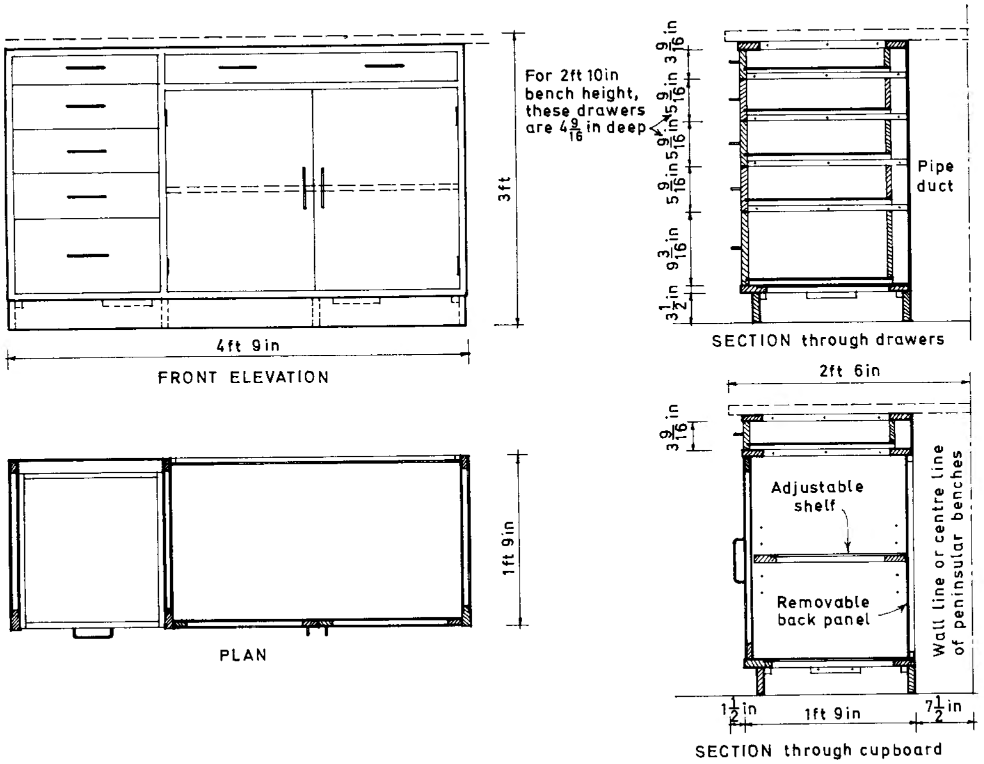

FIGURE 9 *Typical construction details for CSIRO standard bench units; the unit shown is Type D2.*

To quote one instance in an overseas laboratory—the benches were suspended 10 in above the floor, *i.e.* the height was reduced by nearly 20%. When the building was to be extended, the staff (very conscious of the loss of storage space) asked that the 10 in be reduced to 6 in; this, of course, made cleaning extremely difficult. The obvious query is why not reduce the height still further by standing the unit with its $3\frac{1}{2}$ in base on the floor? However, it is agreed that circumstances can alter cases. In a CSIRO laboratory recently built in the Northern Territory where there is a serious termite problem, a steel frame was used and the benches were suspended 6 in above the floor. Despite the floor-cleaning difficulty, this was considered the best solution because it made it easier to inspect for termite galleries.

An interesting recent development overseas is a cast epoxy bench top with integral backboard. It is installed by tilting it until the backboard fits into a rebate in the front of the raised service strip, and it is then lowered until it rests on the top of the bench unit—a simple and speedy

operation. However, I understand that this type of bench top is available only in the United States of America at present, and it is expensive. The idea is good and it is quite possible that, with improved production, materials and finishes, it could become the almost perfect bench top.

Over the years it has been necessary to provide several variations of the standard bench units.

Mobile units

In some virology and bacteriology laboratories, where extreme cleanliness is imperative, the bench units should be mobile so that all wall and floor surfaces can be sterilised. Again, some scientists like to have a unit alongside them whilst they are working at the main bench, so it needs to be mobile.

Reversed units

There should be a nest of drawers beside each writing space. On one side of the bench, this is provided by a standard D1 unit; on the other side, it should be a D1 in which the nest of drawers is at the right instead of the left-hand end.

Drying cupboards

The two cupboards in an F1 unit are lined with asbestos board; each has a 250 W finned element and air inlet and outlet slots.

BENCH HEIGHT

For many years a bench height of 2 ft 10 in was accepted as being a satisfactory standard and there are still many scientists who prefer this height. However, 3 ft is becoming more general and is recommended. For some types of work, benches should be at table height, *i.e.* 2 ft 6 in.

BENCH TOPS

What is expected of a bench top? It should be solid, have a smooth, impervious, hard-wearing surface and it should withstand heat and be unaffected by chemicals; it should be hard enough not to scratch easily, but at the same time not be harsh on glassware.

Although there are many materials which very nearly meet all these requirements, to date there is not one which completely meets all of them. The widest range is available in the USA where the old reliable birch or maple with carbonised finish has been largely replaced by the following:

particle board with baked epoxy or plastic laminate finish;
cast epoxy sheet with integral coved back skirting and raised front edge;
Colorlith, a compressed asbestos cement sheet; it is available in several colours and in thicknesses from $\frac{1}{4}$ to $1\frac{1}{4}$ in;
Coloceran, a more recent development of Colorlith with a bonded ceramic-like inorganic surface; it is also available in several colours and in thicknesses from $\frac{1}{4}$ to $1\frac{1}{4}$ in;
Pyroceram, a glass ceramic sheet with a matt grey non-glare finish; it is available in sheets 8 ft by 4 ft and the thickness is 0·3 in.

Colorlith is slightly marked by some chemicals, but Coloceran and Pyroceram are completely resistant to all except hydrofluoric acid which causes slight etching. In this regard, they are better than timber, but it must be remembered that they are double or treble the price; another advantage is that they are available in colours and this fits in with present-day thinking. Points against them are that the surfaces are extremely hard and joints are required because the maximum sheet length is 8 ft.

In England, teak was commonly used, but in recent years substitutes such as iroko, teak face veneer on corestock and compressed asbestos cement sheet have become popular, mainly because they are cheaper. In Europe, ceramic tiles set in epoxy resin are common; again, these are completely resistant to all chemicals except hydrofluoric acid. Klingenberg tiles are available in several colours and in a range of special tiles for coves, return ends and pipes through the bench.

In Australia, timber is preferred for bench tops which will be subjected to the most severe chemical and physical treatment; compressed asbestos cement is also used, but to a lesser extent. Where conditions are less severe, tops sheeted with plastic laminate, vinyl, linoleum or plywood can be entirely satisfactory—for example, in a bacteriology laboratory, white plastic laminate would be considered by many as the best choice; for physical laboratories and instrument makers' benches, a vinyl or linoleum surface is excellent; stainless steel is the ideal material for radioisotope or oil laboratories. For isolated laboratories in hot dry climates, a solid timber top could be cracked or warped by the time it was delivered; compressed asbestos cement or a framed top sheeted with marine-quality plywood would be a better choice. Timber has the advantage that it is rigid, it extends the full length of the bench and there are no joints to contend with, and it provides a very pleasing working surface. As yet, no preparation has been marketed which will completely protect the surface from chemical attack and heat; but, with normal care and the use of bench mats, this need not be a real problem.

It will be seen, therefore, that the bench top material selected must be related to its specific use; of course, cost is a factor and sometimes geographic location.

Solid timber

The traditional timber for this purpose is teak, but in Australia it is expensive and the supply is poor. Queensland kauri is commonly used and is a very good substitute, but locally grown timbers such as ash in Victoria, jarrah in Western Australia, celery top pine in Tasmania and imported iroko (Africa) and kauri (Pacific Islands) have given satisfaction. Queensland kauri is a close-grained light-coloured timber with an even texture and low shrinkage, but it is a little softer than teak or ash.

It is important that the timber used in bench tops be first-quality—selected for colour if a clear finish is required. Accurate machining and jointing are essential and a high-quality polished surface is dependent on particularly fine sanding.

The tops are made up from boards generally not less than 6 in nor more than 10 in wide. Quarter-sawn (radial) timber is better than back-sawn (tangential) because the movement is less; one wide back-sawn board can cause warping and subsequent rejection of a top. With few exceptions, end joints should not be permitted. It is not necessary to use timber thicker than $1\frac{1}{2}$ in which gives a finished thickness of $1\frac{1}{4}$ in. Bench top projection is $1\frac{1}{2}$ in, with drip mould under.

Movement in timber tops

In order to avoid subsequent shrinkage, warping and cracking, it is essential that the timber be kiln-dried to a moisture content approximating that which it will attain in use; in Melbourne,

this should be in the range of 9–12 %. Timber will gain or lose moisture until it is in equilibrium with the relative humidity of the surrounding atmosphere. To illustrate this, moisture content readings of bench tops which have been in use for a number of years were taken at five locations in each of two buildings. In one which is air-conditioned, over a period of two years the moisture content varied between a maximum of 12½ % and a minimum of 9¼ %; in the other building which is centrally heated, during the same period the range was between 10¾ and 7½ %. This moisture content variation will cause continual movement of the timber; surface coatings will retard it, but they will not prevent it. Movement per inch of width per 1 % moisture content change for several timbers is shown below:

Timber	*Quarter-sawn radial (in)*	*Back-sawn tangential (in)*
Teak	0·001 0	0·002 2
Iroko	0·001 0	0·001 5
Queensland kauri	0·001 4	0·001 7
Victorian mountain ash	0·002 0	0·003 1
Jarrah	0·002 4	0·003 0

From the above it will be seen that, in a 2 ft 6 in wide bench top of quarter-sawn kauri, a change of 3 % in the moisture content will cause a movement of approximately ⅛ in; with some timbers, this could be ¼ in. It is for this reason that solid timber bench tops must be fixed in such a way that it is possible for movement to take place, *i.e.* by using timber or metal buttons, or slotted holes. For all practical purposes, it can be assumed that solid timber does not move longitudinally.

The moisture content of particle board, when marketed, is generally within the range of 6–10 %, and the movement between 0 (oven dry) and 25 % (saturation) amounts to 7 % in thickness and 0·7 % in width and length. An increase of 1 % in moisture content in a bench top 10 ft by 2 ft 6 in would result in an increase of 0·034 in. in length and 0·008 in. in width. In fact, an increase of 4 % is not unusual; this would cause an expansion of slightly more than ⅛ in. in length and $\frac{1}{32}$ in. in width.

Movement in plywood is about 75 % that of particle board. As 80 % of this occurs in the moisture content range 0–8 %, plywood can be regarded as having no movement under normal conditions, *i.e.* when the moisture content is above 8 %.

Framed and sheeted

Select-quality timber suitable for bench tops is becoming increasingly difficult to obtain, and it is likely that framed and sheeted tops will be used more extensively in the future. Again, the recommended finished thickness is 1¼ in, *i.e.* ½ in ply on ¾ in frame; anything thicker is unnecessary and wasteful and anything less looks skimpy. Face materials are plastic laminate, vinyl, linoleum or plywood; end joints should be avoided, but as vinyl and linoleum are supplied in rolls, and plastic laminate sheets are available in lengths up to 12 ft, this problem arises only occasionally. If plywood is to be used, it should be marine-quality and be selected for sheet size, colour and appearance; if possible, the face veneer should be thicker than usual. A timber edge strip—tongued and glued—is recommended.

Finishes for timber bench tops

For many years, nearly all bench tops were finished with aniline black, and this is still used occasionally. Details of this preparation and its application are given in Appendix 3.

Nowadays there is a wide divergence of opinion regarding the most suitable colour for a bench top. Many scientists argue strongly that black is still the best because, with this background, a brown or purple stain is not conspicuous, and it is easier to read calibrations on glassware and to see small amounts of precipitate or any dust. Others favour a clear or coloured finish; they claim that black is funereal and that the possibility of stains does not really matter.

There are many epoxy resin, polyester and polyurethane preparations to give black, clear or coloured finishes. They all have very good (but not complete) resistance to acids, alkalis and organic solvents. A very smooth surface slightly increases resistance to chemicals; it is important, therefore, that the bench top should have a finely sanded surface with a buffed gloss finish.

In order to avoid an unequal moisture absorption which could cause warping, the underside of a timber bench top should be sealed, and two coats of a clear plastic are recommended; this also applies to plywood and particle board.

Bench mats

With reasonable care and the use of bench mats, a bench top will remain in excellent condition for many years. Suitable materials for mats are compressed asbestos cement, low-density polythene, coloured glass or Pyroceram.

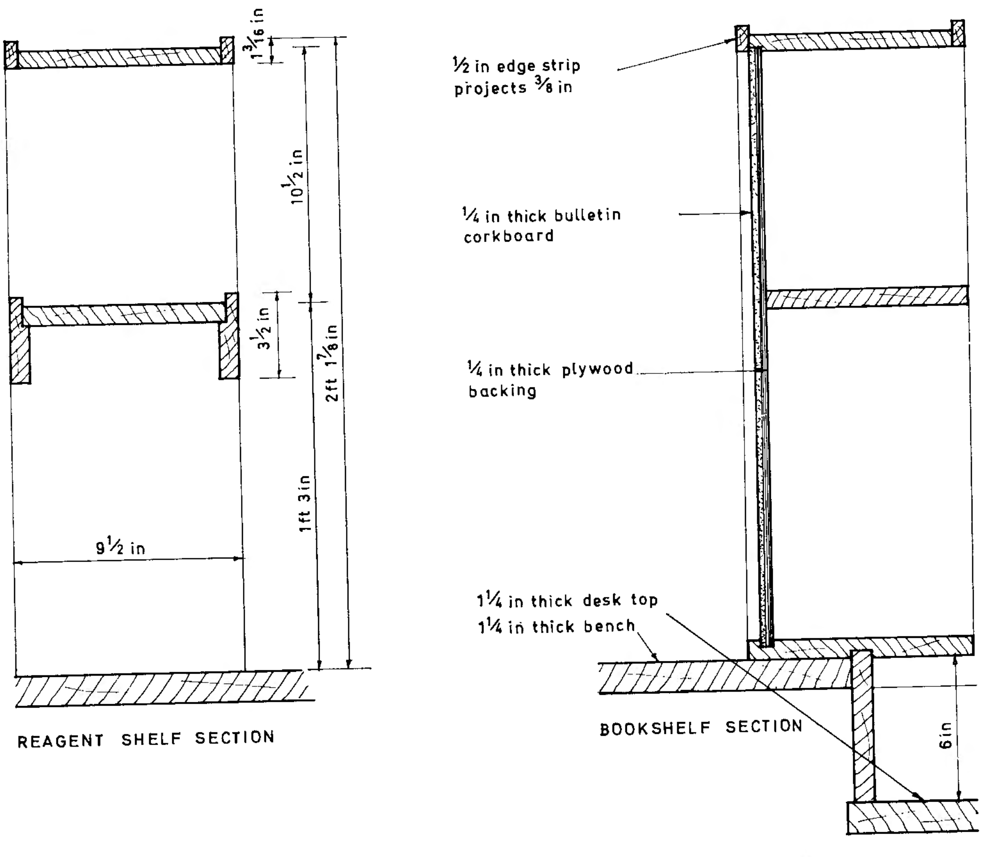

FIGURE 10 *Construction details for CSIRO standard reagent shelf unit.*

REAGENT SHELVES

In chemistry laboratories, most benches are fitted with reagent shelves. In some types of laboratories two shelves are required, but in others one shelf is adequate and it is a mistake to provide a second because it will only be cluttered with unnecessary bottles. The lower shelf and supports can be boxed in to accommodate pipes; this also provides a suitable mounting for service outlets (especially power) and keeps the bench top clear.

Details of the CSIRO standard fitting are shown in Fig. 10. The shelves have a raised edge to prevent bottles being pushed off accidentally. It is usual to protect the shelves; glass and stainless steel have been used, but low-density polythene sheet $\frac{1}{8}$ in thick, loose laid, provides a non-slip, chemical-resistant surface at less cost, and is recommended. Polythene saucers under individual bottles can also be used.

WRITING SPACES

Writing spaces should be provided for all laboratory assistants. A convenient place is at the window end of a peninsular bench, and the top should be 2 ft 6 in high with a plastic laminate or vinyl surface. The reagent shelves are extended to form bookshelves, and the back of these is faced with Krommenie bulletin-board cork for use on the opposite side of the bench. An alternative is to use 4 ft by 2 ft 6 in tables along one of the end walls; adjustable shelves can be fitted above.

SINKS

Materials used are stainless steel, vitreous china and PVC. It is a good idea to check the dimensions because quite often sinks are larger or deeper than really necessary; this means loss of bench space, a backache for somebody and additional cost.

Stainless steel

Nowadays stainless steel is used extensively for wash-up sink and drainer units, and for individual sinks and troughs for other than the most severe conditions. It provides a jointless surface which is not as hard as ceramic, and there is almost no limit to the design and size of units which can be fabricated to meet special requirements.

Individual sinks and troughs have a rim with fixing screws welded to the underside. This obviates a troublesome joint between bench top and sink, and the edges of the hole are protected—of particular value when the bench top is laminated.

In CSIRO there are sinks which have been in use for 20 years and are still in excellent condition. I have heard of only one case of failure—caused by weak hydrochloric which had been allowed to lie in the sink for several days; but, after all, this is not good housekeeping. Stains can generally be removed with steel wool, but it is important that an abrasive cleaning powder be used afterwards, otherwise rust marks will appear.

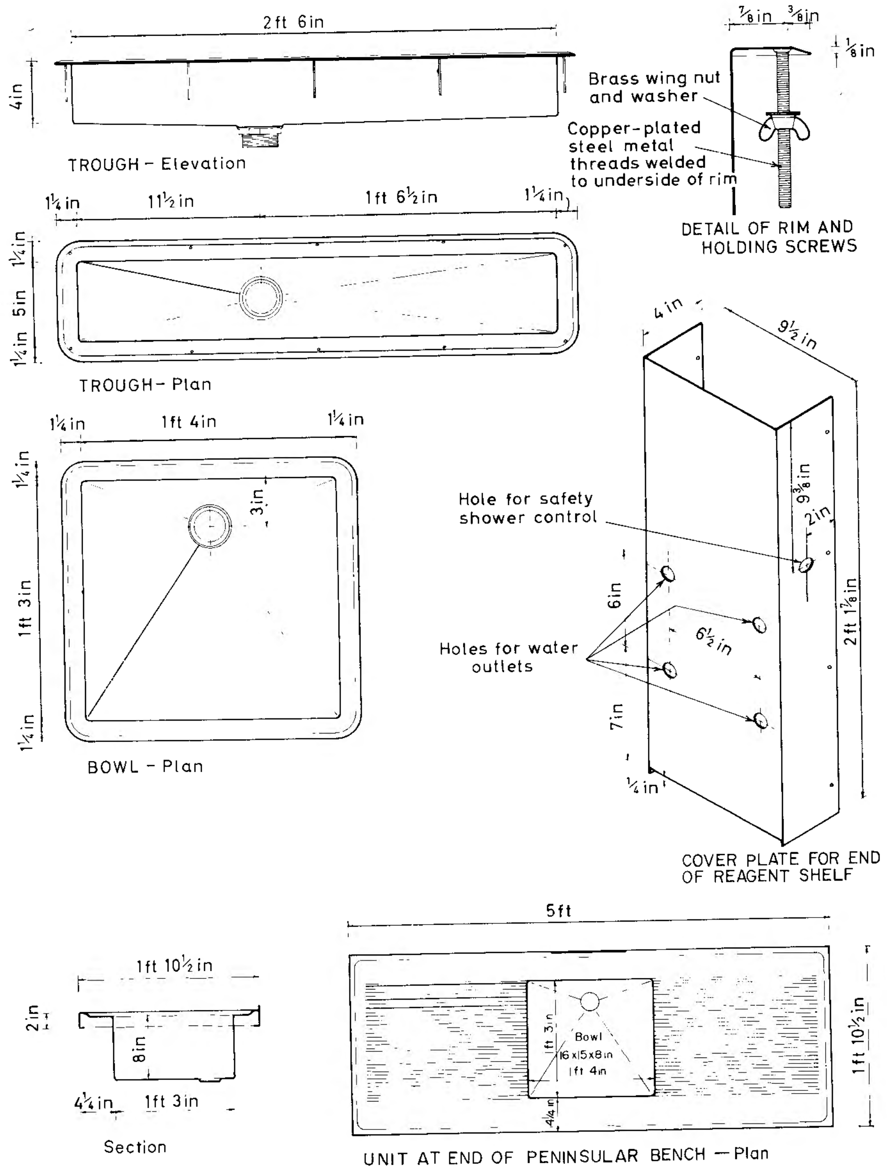

FIGURE 11 *CSIRO standard stainless steel laboratory sinks.*

Details of the CSIRO standard units are shown in Fig. 11. The grade of stainless steel used is No. 316–18/8 austinitic chrome nickel steel containing 2% molybdenum. It is manufactured in rolls in a number of widths; for minimum cost, consideration should be given to the width of the unit and the height of the back, etc., to avoid cutting to waste. The higher cost of molybdenum quality for laboratory use certainly is warranted; so also is the use of 18-gauge instead of 20-gauge. Satin finish is entirely satisfactory and therefore the extra cost of mirror finish is not justified.

The units have a backing of particle board glued to the stainless steel and this is protected on the underside with chlorinated rubber paint.

The following small points can be important:

For bacteriological work—where cracks and crevices must be avoided—the undersides of units should be sheeted with galvanised iron and the joints should be soldered.

In a bacteriology kitchen, a flat draining surface is preferable to the standard corrugated finish.

For animal post-mortems, the stainless steel unit should be supported by brackets on the wall rather than legs on the floor. Cleaning is also easier if the radius of internal angles is increased from the standard $\frac{1}{2}$ in to 1 in.

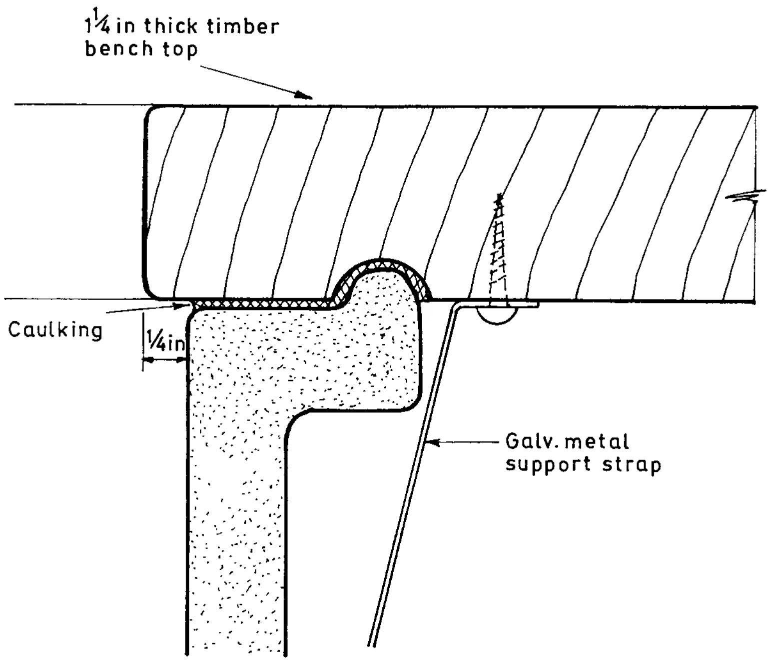

FIGURE 12 *Joint between bench top and vitreous china sink (R. Fowler Ltd Monash type).*

Vitreous china

The standard type has a straight flange and the outlet is bevelled to fit a Vulcathene or stainless steel plug and washer. The Monash type has a rebated flange which facilitates a water-tight joint to the underside of the bench top (*see* Fig. 12); it also has an integral outlet which is a decided advantage when severe chemicals are being used.

Vitreous china has high impact resistance, it is not subject to crazing and discolouration and it resists even hot concentrated acids and alkalis—provided, of course, that they are promptly washed down.

For trace element investigations where chromic acid is used to clean the glassware, the sink should be vitreous china and the drainer should be timber. There is a risk of the glassware being contaminated if stainless steel is used.

Plastics

Rigid polyvinyl chloride sheet can be fabricated into sink and drainer units, tanks and trays; the sheet is generally $\frac{3}{16}$ in thick and the joints are welded. Again, particle board backing should be glued to the underside of the drainer and also to the sink—in case hot water is used; the backing should be finished with chlorinated rubber paint.

TROUGHS AND DRIP CUPS

In student laboratories, full-length runnels of stainless steel, PVC or polythene are used quite often, but in research laboratories troughs or drip cups are preferred because they occupy less bench space.

The standard CSIRO trough 30 in by 5 in by 4 in (*see* Fig. 11) is used with a four-tap fitting over (*see* Figs. 1 and 7). Individual 7 in by 4 in moulded Vulcathene drip cups are available, but many laboratory workers consider them too small and prefer a 12 in by 6 in or 8 in by 6 in stainless steel trough.

TAPS

In the early 1940s, wartime difficulties of supply made it necessary for CSIRO to design its own laboratory taps and arrange their manufacture and these are still being used. In recent years, a comprehensive range of well-designed imported taps has become readily available commercially and these are now being used quite extensively.

The CSIRO taps are brass—$\frac{1}{2}$ in jumper type; the tubing is $\frac{13}{16}$ in by 13-gauge brass and the joints are brazed. Hexagons are provided on all fittings to facilitate fixing; tapered nozzles and adapters are available for screwed connections. Most of these fittings are chrome plated, but grey epoxy is becoming increasingly popular and is the finish used on swan-necks, etc. in fume cupboards.

The imported Marklab valves are brass—$\frac{3}{8}$ in with smooth easy-clean surfaces. The tube is brass with a minimum thickness of 10-gauge; swan-necks are made from 16-gauge tube and they are either fixed or swivel. All types of bench and wall fittings are supplied with integral screwed tails and backnuts with locating lugs which eliminate screw-holes in the flanges. The standard finish for all fittings is black polythene and they have handwheels with lettered coloured inserts. Recently the jumper valve has been largely superseded by a diaphragm valve of improved design and performance; the rubber diaphragm, when closed, is in the relaxed position and when open it is compressed. These valves are glandless and therefore friction is greatly reduced. They are designed to control hot and cold water, gas, compressed air, vacuum and high-pressure gases; for distilled water, special fittings are available, including a swan-neck in which all the contact surfaces are plastics. Needle valves suitable for up to 100 lb/in^2 are available; they have stainless steel floating-tip spindles which self-align into a brass seat.

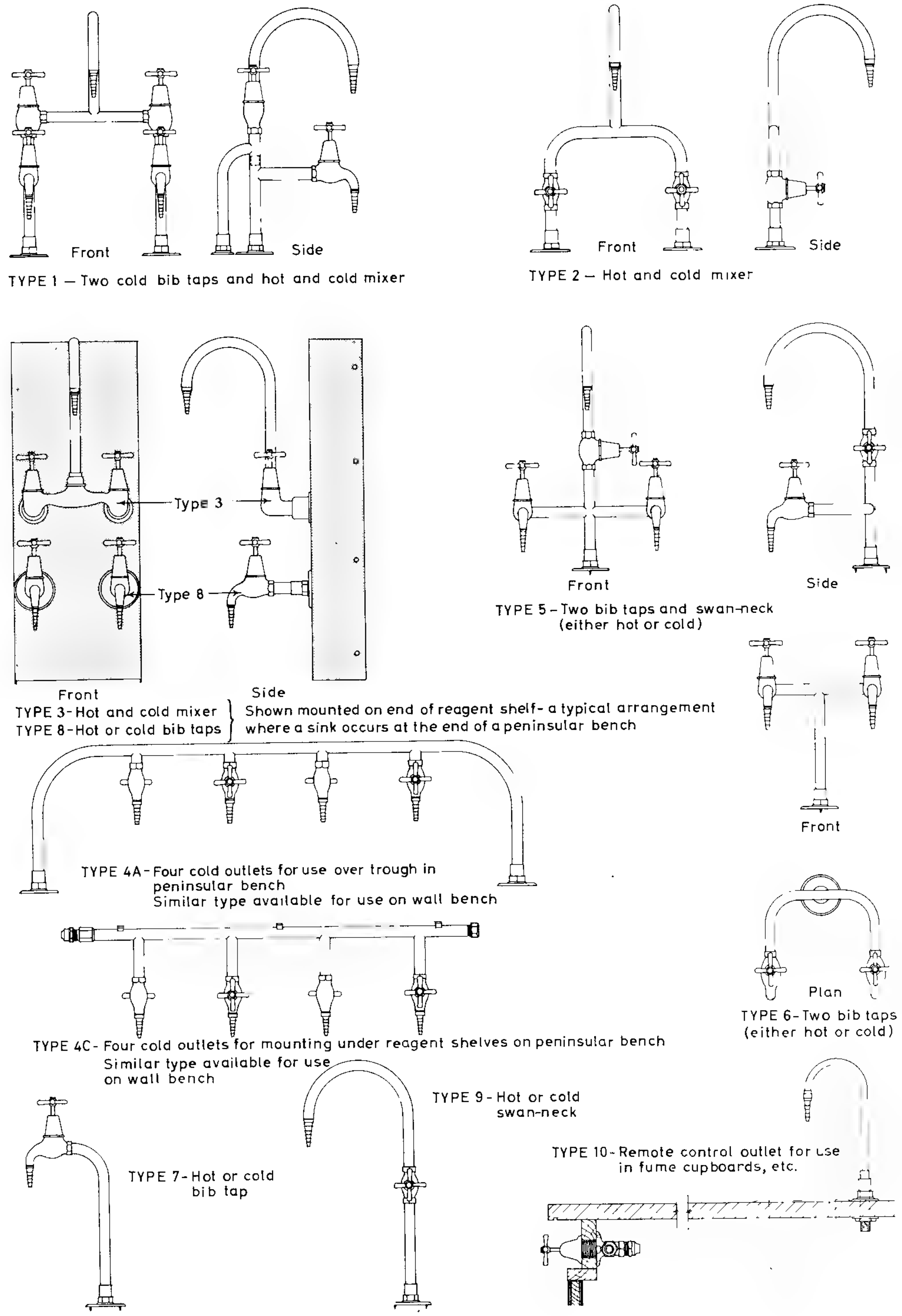

FIGURE 13 *CSIRO standard taps.*

DRAINING RACKS

Peg boards are used, either made of timber or, occasionally, stainless steel; in both cases, the ends of the pegs are fitted with plastic caps. Nowadays polythene-coated wire racks are gaining popularity; they are less expensive and can be made up to any size (*see* Figs. 7 and 8).

The functions of a draining rack and a drying cupboard have been combined in a unit marketed in the United States of America; it is fitted with a heater and fan, and air at 160°F is blown through the pegs which are polypropylene tubes.

FUME CUPBOARDS

The function of a fume cupboard is to protect laboratory personnel from dangerous fumes and to contain any minor fires or explosions which might occur. It must be designed to collect and disperse the fumes without risk of them re-entering the laboratory through windows or fresh-air supply ducts. The quantity of air from the laboratory required to purge the cupboard must be a minimum, and air turbulence within the cupboard must also be a minimum. All internal surfaces must be chemical-resistant.

Nowadays more and larger fume cupboards are being used and it is vitally important that location, design and the materials of construction be given careful consideration.

Location

For maximum economy and efficiency, a fume cupboard should be located so that the exhaust duct can be vertical; bends and horizontal runs should be kept to an absolute minimum. It should be in a draught-free position because excessive air movement across the face of a cupboard will prevent it functioning properly. The velocity of the air being exhausted through a cupboard is quite often less than that of air currents entering the room through an open door or window or through air inlet registers; it can even be less than air disturbance caused by a person walking in front of the cupboard. Also, a fume cupboard should be in a position where, in the event of fire, access to the door is not obstructed; of course, if there is an alternative exit, this point does not arise.

In buildings where there are heated-air or air-conditioning systems, there is an advantage in having some of the fume cupboards grouped in rooms between laboratories. If this is done, each room has its own supply of partially heated air.

Design

The satisfactory performance of a fume cupboard requires that contaminated air does not reach the breathing zone of the operator. To achieve this, tests indicate that the velocity across the face area of the fume cupboard opening should be uniform and not less than 50 ft/min; in practice, 60 ft/min is generally adopted as a safe working minimum and this is increased to more than 300 ft/min when the sash is lowered to give a face opening 6 in high. It can be seen, therefore, that with higher overall face velocities, the incoming air can cause problems; there can be excessive turbulence, gas flames can be blown out and, in fact, the air can rebound out of the cupboard.

In order to obtain an even distribution of air across the fume cupboard, baffles are fitted at the back and at the top, thus forming two (or preferably three) full-length slots. Heavy fumes are

exhausted through the bottom slot and light fumes and heated air through the top back slot; the top front slot picks up any fumes which have not been drawn into the back slot and have rolled forward.

Types of fume cupboards

Open front

This is the simplest and least costly cupboard and it is entirely satisfactory where conditions are not severe.

Sash

Details of the CSIRO standard cupboard are shown in Fig. 14. It has baffles at the back and top and these provide three slots the full length of the cupboard. The bottom slot is $1\frac{3}{4}$ in wide and 7 in above the bench top; the two top slots are $1\frac{1}{4}$ in wide. One 40 W 4 ft fluorescent tube is fitted into a vented box which is either painted or lined with white PVC; it is protected from acid fumes by a $\frac{1}{4}$ in thick Perspex panel with neoprene gasket. A plenum is provided and the outlet to the duct is central at the top. The mullions are fitted with removable covers, providing a place for cables to power outlets and switches for the exhaust fan and light; it also accommodates the occasional pipe to service outlets.

Bypass

The bypass cupboard has been developed to overcome the problems which can occur if there is a high-velocity jet of air when the sash is in the low position. In this type of cupboard, an inlet grille is provided above the sash, as shown in Fig. 15. When the sash is fully raised it blocks the inlet grille and all the air enters through the sash opening. The quantity of air entering through the grille increases as the sash is lowered, but the combined volume through it and the sash opening is constant, *i.e.* regardless of the position of the sash, the quantity of air exhausted from the laboratory does not vary and this avoids complications with ventilating or air-conditioning systems.

For air-conditioned laboratories

Air-conditioning—particularly cooling—is an expensive business, and to exhaust conditioned air through fume cupboards seems to be very wasteful. Obviously this is a major consideration in the design of air-conditioning systems for laboratories and the subject is discussed in some detail in Chapter 5.

In order to reduce the quantities of conditioned air exhausted, much attention has been given to the design of fume cupboards with auxiliary air supply. A separate fan and duct system can supply outside air (partially heated when necessary) up to 60% of the total quantity required. The difficulty here is to introduce the auxiliary air into the cupboard by a method that will maintain an adequate uniform velocity over the face opening and yet not cause turbulence within the cupboard.

In Australia, Conditionaire Engineering Pty. Ltd market a fume cupboard in which the auxiliary-air inlet is inside the cupboard; in order to reduce the velocity, the air passes through gauze. In England, some fume cupboards have been manufactured to a design described in an article 'Sashless Fume Cupboards' by M. J. Sanders, Safety Officer at the Ministry of Technology's

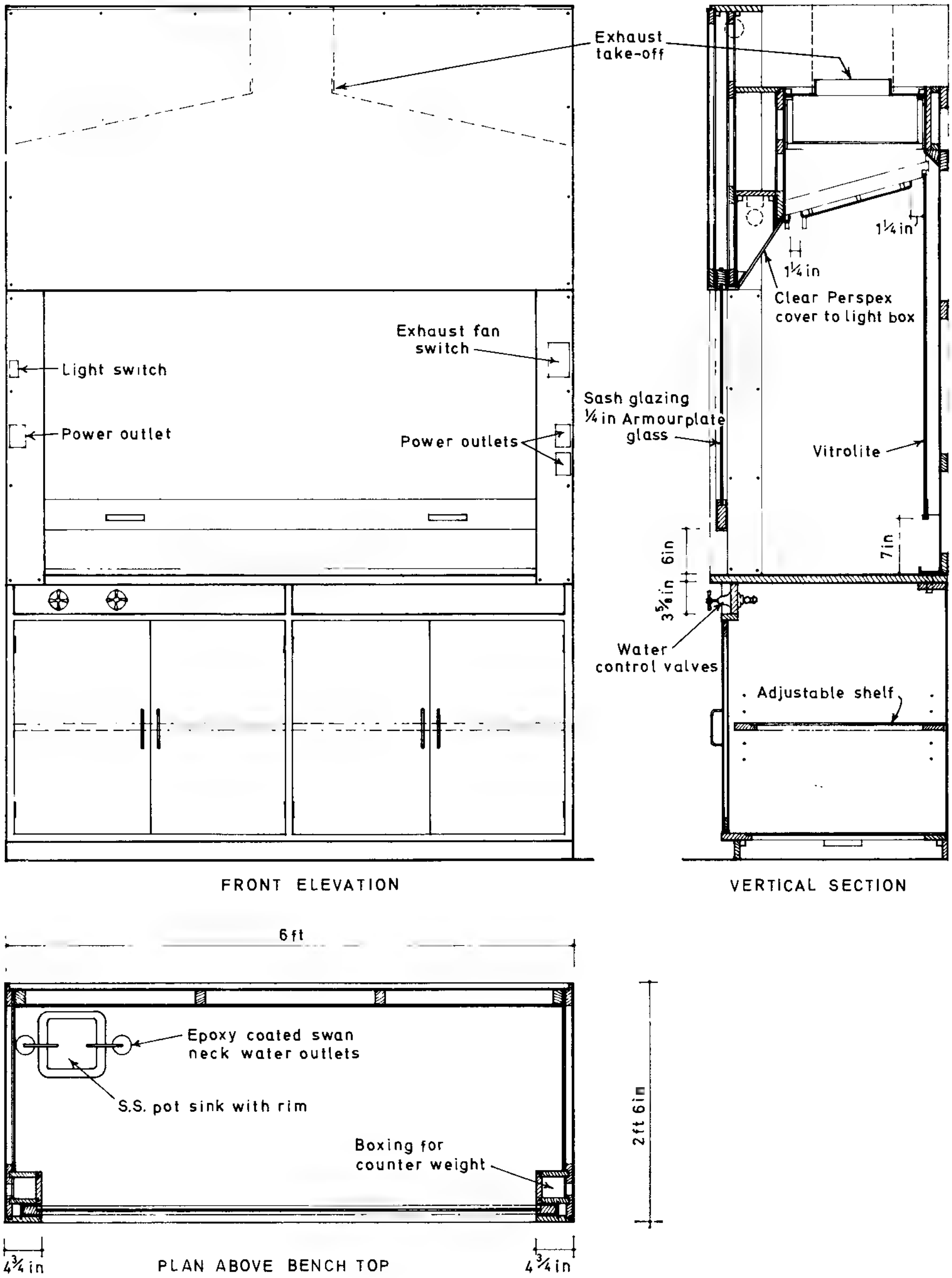

FIGURE 14 *CSIRO standard fume cupboard with sash.*

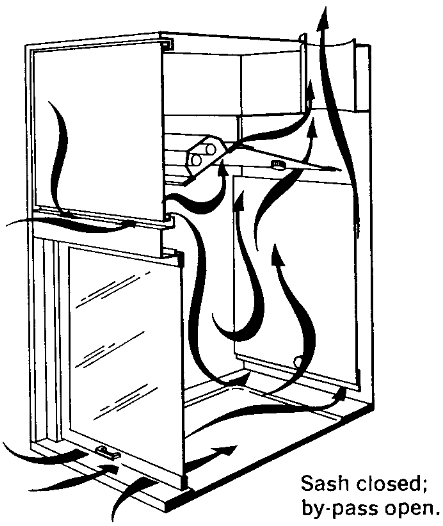

FIGURE 15 *Bypass fume cupboard, marketed by Fisher Scientific Co., USA.*

Warren Spring Laboratory. In both designs, the auxiliary air is intended to form a curtain across the face opening. In the United States of America, most of the auxiliary-air-supply fume cupboards are designed so that the air enters through a louvred panel which projects from the fume cupboard above the face opening, as shown in Fig. 16.

Many scientists say that they are satisfied with the performance of these types of cupboards; in fact, there is some doubt that the flow pattern of the auxiliary air is as claimed. This matter

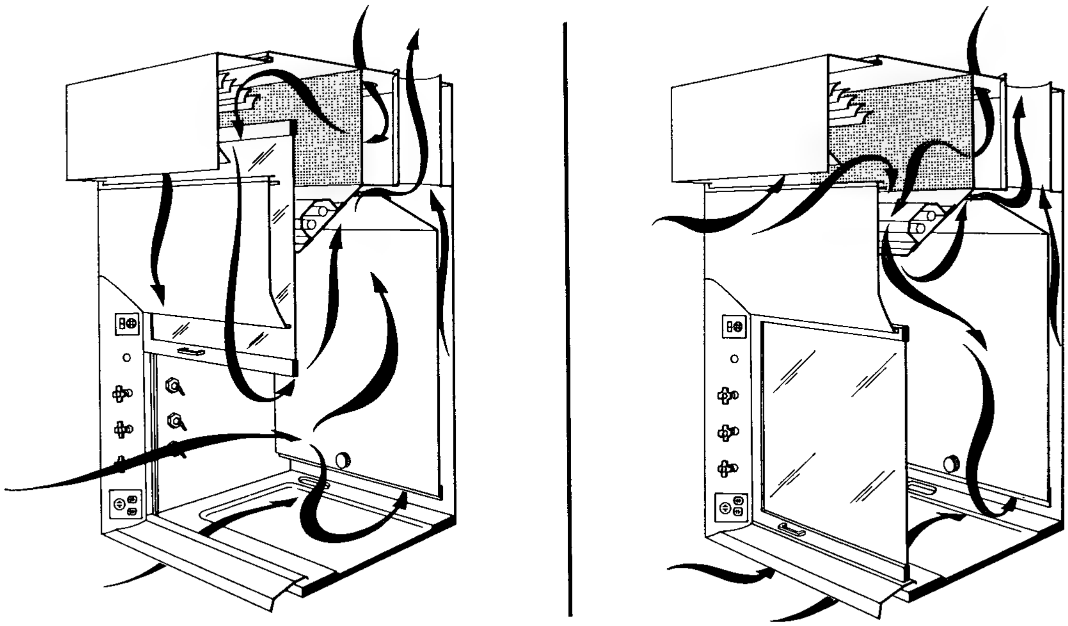

FIGURE 16 *Fume cupboard with auxiliary air supply, marketed by Fisher Scientific Co., USA.*

has been examined and several reports written; in one, 'Evaluation of Laboratory Fume Hoods' by Schulte, Hyatt, Jordan and Mitchell (*American Industrial Hygiene Association Quarterly*, September 1954), the authors state:

> 'It is this detrimental effect of cross drafts which nullifies attempts to provide an independent source of unconditioned or untempered air to a hood. Tests were made on one hood where air was brought in along the sides and top of the hood face to supply about one half of the total amount of air exhausted by the hood. Correspondence with other engineers and observations made in other laboratories have convinced us that the independent air supply is not a solution to the problem of saving heated or cooled air.'

FIGURE 17 *Fume cupboard; Monsanto Chemical Co., Missouri, USA.*

There is another way to solve the problem, *i.e.* to design the fume cupboard so that, whilst the air exhausted is conditioned, the quantity is reduced to a minimum by reducing the area of the face opening. This matter was investigated very thoroughly by the Monsanto Chemical Co. in connection with the design of their Research Centre at Creve Coeur, Missouri. A 6 ft wide fume cupboard was to be provided for each of the four men to be accommodated in each of the 80 two-module 22 by 30 ft laboratories. I quote the following extracts from the report 'Fume Hoods—Safety vs. Costs' by Walls and Metzner:

> 'The hood design must satisfy the size requirements for conducting experiments in all branches of chemical research except radiological.

'It must provide a safe face velocity and use no more than 550 ft^3/min of room air, *i.e.* four hoods require 2200 ft^3/min. An excess of this quantity would result in high discomfort to the occupants. It must be easily balanced as a part of the total air-conditioning system. No air from the laboratory rooms is to be recirculated in order to reduce the danger of experiment contamination.

'The rule-of-thumb correlation between fume hood exhaust and air-conditioning refrigeration is that each 200 ft^3/min exhausted equals one ton of refrigeration which represents \$1000 in capital investment. Thus a conventional 6 ft fume hood having a face velocity of 100 ft/min and an area of 16·5 ft^2 would require an air-conditioning system costing \$8200, to say nothing of the operating cost.

'The conventional fume hood was obviously not acceptable. A very high volume of air (up to 1600 ft^3/min) is required to produce safe face velocity when the hood is open far enough to permit freedom of work. The auxiliary-air hood with internally supplied air was dismissed because it accomplishes absolutely nothing toward reducing the air required from the room to assure a safe face velocity. In fact, our experience with this type of hood was that it tended to "bounce" air out of the hood. The auxiliary-air hood, with supplementary air supplied just outside and pulled through the face of the hood, is a satisfactory choice from the safety standpoint. Again, large quantities of air must be handled. Both of the auxiliary-air hoods must be provided with a bypass to take air from the room when the sash is closed, or the system will be hard to balance. Such a system is also expensive because it requires additional ductwork.

'A prototype was installed and tested in a full size laboratory mock-up. Details of the final design are shown in the photograph (*reproduced in this book as Fig.* 17), and incorporated the following features:

(i) A three-section horizontal sliding sash which yields a face velocity of 120 ft/min in the one third open position and 55 ft/min in the two thirds open position at a total air discharge of 550 ft/min.

(ii) Above the sash is a hinged blow-out panel held in place by magnets. This could relieve pressure within the hood in the event of an accident and reduce the chances of the Saflex safety glass blowing completely out of the frame.

(iii) In order to maintain a balance in the air-conditioning system, the air flow is through the hood at all times. It enters through simple baffles at the sides and along the bottom when the sashes are closed, and through these and the face opening when it is partially open.'

Perchloric acid

Because of the extremely dangerous properties of perchloric acid, all laboratory work involving its use should be done in specially designed fume cupboards which conform to the following:

All internal surfaces should be incombustible and non-porous—for example, polyvinyl chloride (PVC), stainless steel or compressed asbestos cement with epoxy paint finish.

To prevent a build-up in concentration of perchloric condensate, PVC or stainless steel water sprays should be fitted behind the baffle and in the duct. It is important that the position and design of the sprays be such that they wash the entire surface. The water is collected in a trough which extends full length along the back of the cupboard and in one or more drain

outlets in the duct. The sprays can be operating whilst the cupboard is in use or they can be turned on at the end of each digestion. Water falling from the bottom of the back baffle can cause trouble by splashing; in one design, this has been solved by using a strip of polypropylene fibre. The baffles should be removable to simplify regular and thorough maintenance.
Any unsealed crevice is a hazard. All internal surfaces—in both the cupboard and the duct—should be streamlined to avoid ledges where condensate can lodge.
Timber should not be used; even when coated with epoxy or chlorinated rubber, it is subject to attack at joints. Litharge and glycerine should not be used as a cement for bedding plugs and washers in sinks; it absorbs perchloric acid and overheating or percussion can cause it to explode.
Ducts should be stainless steel (avoid the use of rivets) or asbestos cement with chlorinated rubber paint finish.
Each cupboard should have a separate exhaust.

Spot ventilation

Spot ventilation in the laboratory provides a flexible means of exhausting contaminants and, as this is done near their source of origin, relatively small quantities of air are required. Fumes can be exhausted from a small enclosure on the bench or from washing-up sinks and drying cupboards. A mobile unit can be used, as shown in Fig. 18; this type of installation has been simplified by the use of plastic enclosures and flexible PVC ducting.

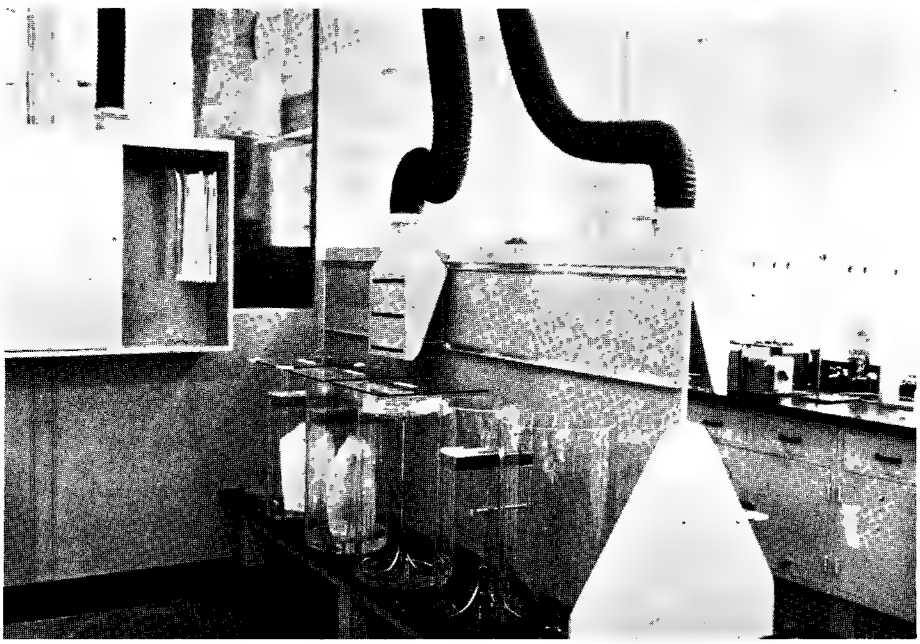

FIGURE 18 *Showing slotted exhaust units for spot ventilation; Upjohn Laboratory, Michigan, USA. The 5 in diameter flexible ducts each exhaust 300 ft³/min. The units are fitted with shut-off dampers, non-sparking wheels, and sliding track. Solvent vapours are exhausted from the drying cabinet at the left at a rate of 100 ft³/min.*

Dimensions

For many years laboratory workers were satisfied with a fume cupboard 4 ft wide, but now there is an increasing preference for cupboards 6–8 ft wide. For practical reasons such as air distribution, duct size and width of sash, 8 ft represents about a maximum. As in the case of bench units, an increase in length means less cost per lineal foot; the installed cost of a 6 ft cupboard, complete with services, is very little more than for a 4 ft cupboard.

A clear height of 4 ft is generally adequate and is recommended, but this should be checked because, for some work, 3 ft is quite sufficient. Then again, heights of 5 ft or more are sometimes required, and these can be obtained either by having a portion of the bench removable or by having a walk-in unit. Most cupboards are 2 ft 6 in deep, but current designs in the United States of America are 3 ft which includes a splayed surround 6 in deep; the extra depth probably improves the air flow into the cupboard.

The CSIRO standard design provides cupboards under the bench top, but variations include acid store (lined with asbestos or PVC, and fitted with a PVC tray), chromatography cabinets or an open shelf for electrical equipment.

Construction

In the CSIRO standard fume cupboard, the frame and sash are timber. The bench top is timber, compressed asbestos cement, stainless steel or acid-proof tiles set in epoxy resin; if tiles are used, the size of the bench top and the sink should be an exact multiple of the tile plus joint, to avoid cutting.

The internal lining is rigid PVC, $\frac{1}{8}$ and $\frac{3}{16}$ in thick—white where it is visible and grey (which costs less) behind baffles. This material is not attacked by chemical fumes and its smooth polished surface has a pleasing appearance; with the careful application of heat, it can be bent to form condensation gutters, etc.

The back baffle is coloured glass—generally white, but black has been used because it is a better background for colour assessment of fumes. To reduce the risk of cracking, it is fitted in panels 2 ft wide which are butt-jointed and supported by clips rather than screws. Timber or stainless steel is used to support the back and top baffles; timber should have two coats of epoxy before fitting. The top baffle is white PVC with edges bent up; this gives added strength and, along the lower edge, serves as a condensation gutter.

Of course, all materials in a fume cupboard should be incombustible, and therefore PVC cannot be regarded as being completely satisfactory. It will distort if subjected to temperatures of about 150°F, and at higher temperatures it will burn—giving off hydrochloric acid fumes; however, it is self-extinguishing. Even when several hot-plates are being used, the large quantities of air passing through the cupboard make it most unlikely that the temperature would rise sufficiently to distort the PVC; if this does happen, it is probably due to carelessness. To avoid this possibility, some people prefer to have the cupboard (including the back and top baffles) lined with $\frac{1}{4}$ in compressed asbestos cement, painted with clear or white epoxy. For some types of work, the lining should be stainless steel which gives flush surfaces and can be coved at internal angles.

Sashes

When a fume cupboard is being used for light-duty work, it is serving the function of an exhaust hood and a sash (quite an expensive item) is not really necessary. However, for most laboratory work, a fume cupboard should be fitted with a sash because it improves the performance and

provides a safety barrier for the operator. Sashes are sliding—horizontal or vertical, or a combination of both. In air-conditioned laboratories, sashes which slide horizontally have the advantage that they reduce the face area of the cupboard (*see* p. 54).

The CSIRO standard fume cupboard has a sash which slides vertically. It has a timber frame and the glass is bedded in an adhesive glazing compound in a $\frac{5}{8}$ in rebate on the inside of the frame. The weights are lead, the wire stainless steel and the pulleys nylon. In order to work in the fume cupboard without raising the sash, small horizontally sliding panels are sometimes provided along the bottom of the sash; alternatively, there can be glove holes. The glass is $\frac{1}{4}$ in thick Armourplate, and some properties of this glass relative to wired glass and laminated glass are set out in Table 1.

TABLE 1. Some properties of toughened, wired and laminated glass

Type of glass	*Resistance to thermal shock*	*Mechanical strength*	*Safety properties in event of explosion*
Toughened—*e.g.* Armourplate	Withstands up to approx. 480°F	4–5 times as strong as polished plate of the same thickness	The glass will shatter, but the particles will be small with relatively blunt edges
Wired	Less than for polished plate, for which the maximum is 120°F	Less than the same thickness without wire	The glass and possibly the wire will break, and sharp-edged particles could be projected at high speed
Laminated—*e.g.* TripleX	Withstands up to approx. 120°F	Same as polished plate of which it is comprised; thus $\frac{1}{4}$ in TripleX is only as strong as one of the $\frac{1}{8}$ in laminations	The glass will fracture and the plastic interlayer may rupture, but the particles will remain bonded to it

If Armourplate is used, it is cut to size and any required holes are drilled before the toughening process. Holes for handles and sash cords reduce the strength of the glass and therefore should be avoided; if they are really necessary, they should be fitted with nylon or red-fibre bushes because it is not good practice to have direct contact between glass and metal. During the manufacture and installation of the fume cupboard, the Armourplate should be handled with extreme care because a knock can produce a stress condition which, although impossible to detect at the time, can cause the glass to shatter if it receives another knock or is exposed to a sudden temperature change.

Testing and maintenance

Every fume cupboard should be thoroughly tested before it is accepted. A velometer is used to obtain the air velocities at, say, four positions across the bottom, the centre and the top of the face opening; readings should also be taken along the length when the sash is down to heights of 12 in and 6 in above the bench. The easiest method of testing is with an electrically operated

portable insecticide fogger which generates large quantities of dense fog, although the high velocity discharge can be a disadvantage for some tests; in this case, smoke should be used. In Australia, the source of smoke is usually improvised, but smoke candles can be obtained—for example, E. Vernon Hill & Co., Wisconsin, USA, market two sizes; one is a half-minute candle which produces 4000 ft^3 of a light-grey, odourless and non-toxic smoke, and the other is a 3-min candle which gives 40 000 ft^3.

Even if it remains a pious hope, it would be good to think that all fume cupboards—including the ducts, fans and motors—were cleaned and checked once a year.

BALANCE AND INSTRUMENT BENCHES

The location of balances and sensitive equipment is most important, and the following points should be considered:

Under no circumstances should it be possible for sun to shine directly on to instruments.

Excessive air movement must be avoided; instruments should not be exposed to draughts from doors or windows, or to air currents from central-heating radiators. If the room is air-conditioned, care must be taken with the design, particularly the type and position of vents.

Good natural and artificial lighting is essential so that the operator is not bothered by either glare or shadow. Facing a window is not suitable; even a south-facing window generally is unsatisfactory because of glare. Quite often a magnifying attachment is fitted to a balance—to prevent glare on the scale, rather than to magnify it.

Instruments should not be placed in a constant traffic way.

In order to obtain the most rigid base, instruments should be set up over beams rather than slabs and close to columns rather than mid-span.

Balances and instruments in frequent use must be strategically placed. Current practice is for weighing to be done within the laboratory rather than in a common balance room along the corridor. Quite often semi-microbalances (precision $\pm 0{\cdot}01$ mg) are provided in the laboratory; in many, satisfactory readings can be obtained from a macrobalance ($\pm 0{\cdot}05$ mg), even if it is supported on a timber bench top.

If trouble with vibration is suspected, a simple test is to place a beaker of mercury on the floor and observe the surface; instruments for measuring the amplitude are also available. Various methods of exciting the building structure should be tried—for example, a person running heavily along a corridor or slamming a cold room door.

A simple bench with a heavy top will meet most requirements if, in the planning and design of the building, adequate precautions have been taken to deal with vibration (*see* p. 25). In basement or ground-floor rooms, the recommended bench is a 2 in slate or $2\frac{1}{2}$ in thick reinforced concrete or terrazzo slab on brick or concrete piers; the latter should be independent of the structure and the floor. For rooms above ground level, a similar top can be used on a steel frame, but there must be vibration-isolating material between them. Details of the CSIRO standard balance and instrument bench are shown in Fig. 19.

With the modern balance, weighing is generally a standing rather than a sitting operation; an increased bench height therefore provides more convenient reading. Assuming that the optical

scale is 1 ft 2 in above the slab, a total height of 4 ft 6 in can be obtained by increasing the bench height from the standard 3 ft to 3 ft 4 in.

An instrument should maintain its level so that it is not necessary to make frequent adjustments. As desiccators, etc. have to be placed on the bench top and readings recorded, it is sometimes desirable to have the writing surface independent of the balance support.

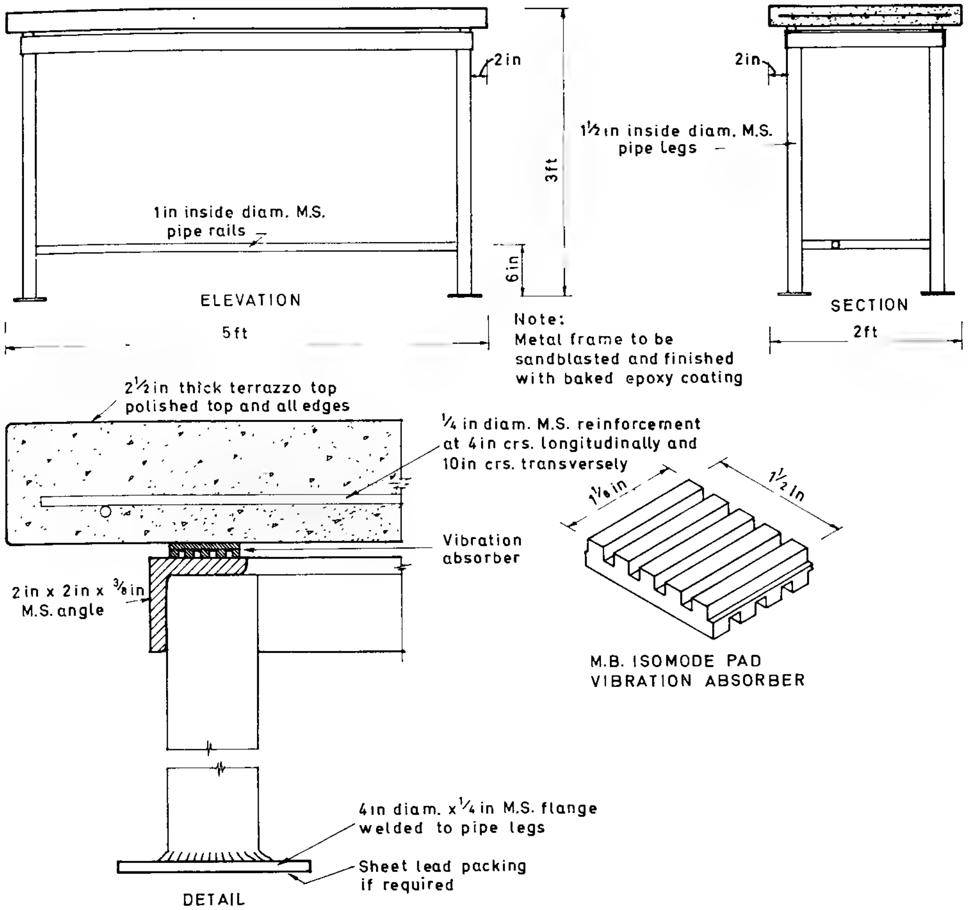

FIGURE 19 *CSIRO standard balance and instrument bench.*

The most commonly used vibration-isolating material is ribbed neoprene; the ribs on one side are at right angles to the ribs on the other, as shown in Fig. 19. The maximum efficiency is obtained when it is loaded to 50 lb/in^2 and the area of each pad is calculated accordingly; at this loading, the thickness of $\frac{5}{16}$ in is compressed to $\frac{1}{4}$ in.

Air bags have been used quite effectively to isolate vibration. At the David Rivett Laboratory (*see* p. 104), an electron microscope was installed on a suspended floor; photographs of

up to 200 000 magnifications and exposures of up to several seconds were required. The equipment (which weighs approximately half a ton) is mounted on eight air bags, a $\frac{1}{2}$ in thick steel base plate and eight 6 in by 6 in Isomode neoprene pads (*see* Fig. 20). The air bags are butyl rubber of the type commonly used in motor car heavy-load air springs; they are approximately 4 in. in diameter by 7 in long, with a wall thickness of $\frac{5}{16}$ in. No additional damping is required, but

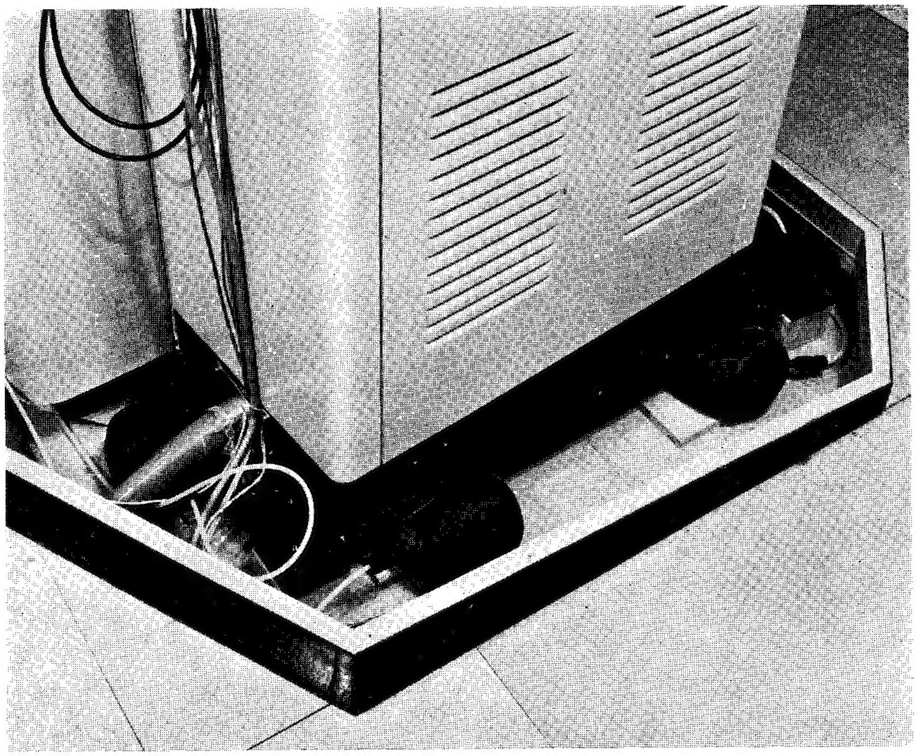

FIGURE 20 *Anti-vibration of electron microscope, using air bags and Isomode pads; CSIRO David Rivett Laboratory, Clayton, Vic.*

blocks with about $\frac{1}{16}$ in clearance have been placed at the four corners to restrict excessive movement. A troublesome vibration was transmitted through the high-voltage lead to the top of the machine; this was very simply and effectively absorbed by supporting the lead on two spiral springs fitted to the wall.

MICROSCOPE CUPBOARDS

The modern microscope with its numerous attachments is not readily stored in an under-bench cupboard; most scientists prefer to have it housed in a cupboard on the bench. Details of the CSIRO standard unit are shown in Fig. 21; the depth of the instrument should be checked because

sometimes it is necessary to increase the cupboard from the standard 2 ft 3 in to 2 ft 6 in. The internal finish is a matter of personal preference; some like matt black, others white and others again prefer the appearance of clear-finished timber. If it is considered necessary to lock the cupboard, a three-leaf door is fitted instead of the roller blind.

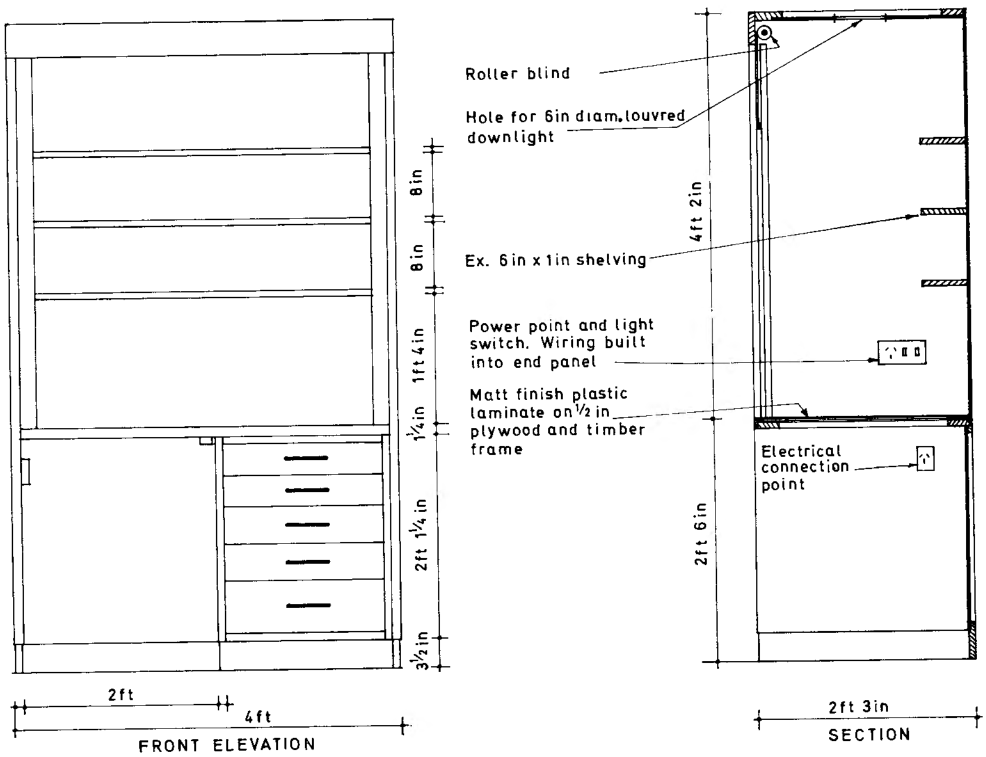

FIGURE 21 *CSIRO standard microscope cupboard.*

TITRATION BENCHES

Details of the CSIRO standard unit are shown in Fig. 22. As drawn, the top is at bench height, but occasionally table height is preferred.

SPECIAL BENCHES

Standard bench layouts can be adapted to meet most situations, but there are always exceptions which require individual treatment. The arrangement shown in Fig. 23 was designed to house five auto-analysers, and I am including a few details because the basic idea could very well be applied in other laboratories where there are a lot of instruments.

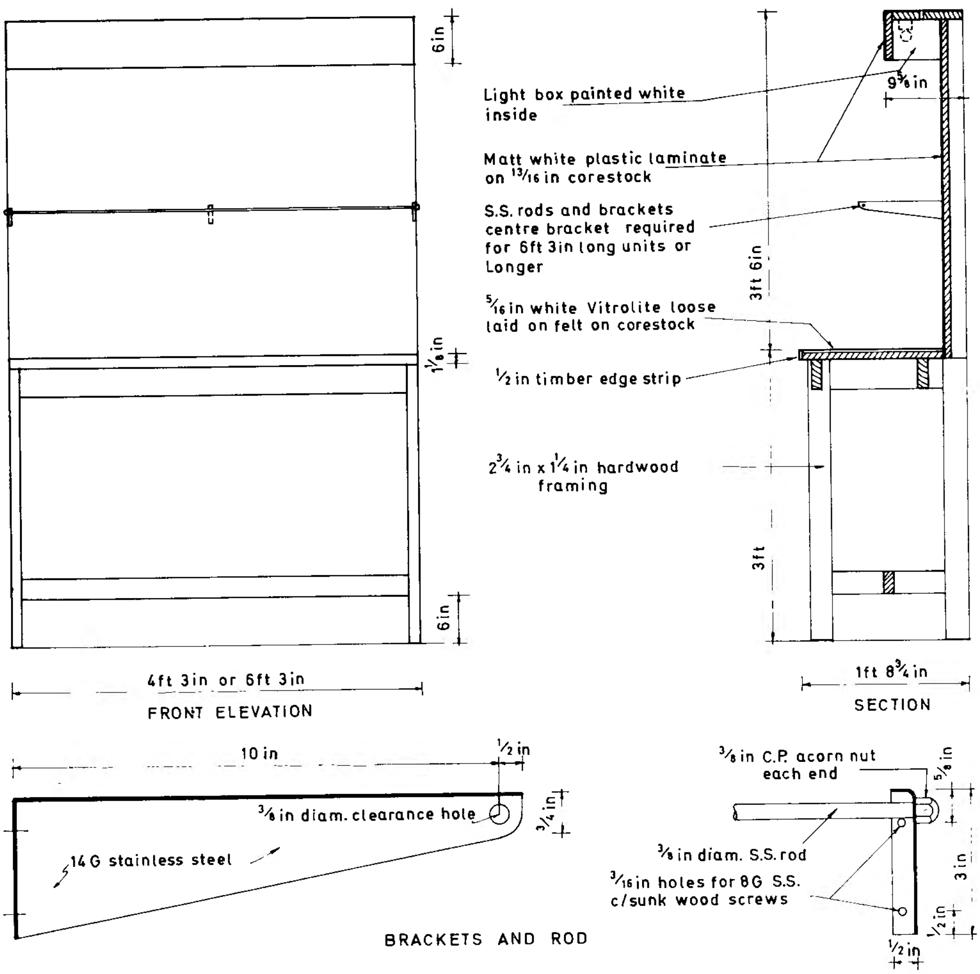

FIGURE 22 *CSIRO standard titration bench.*

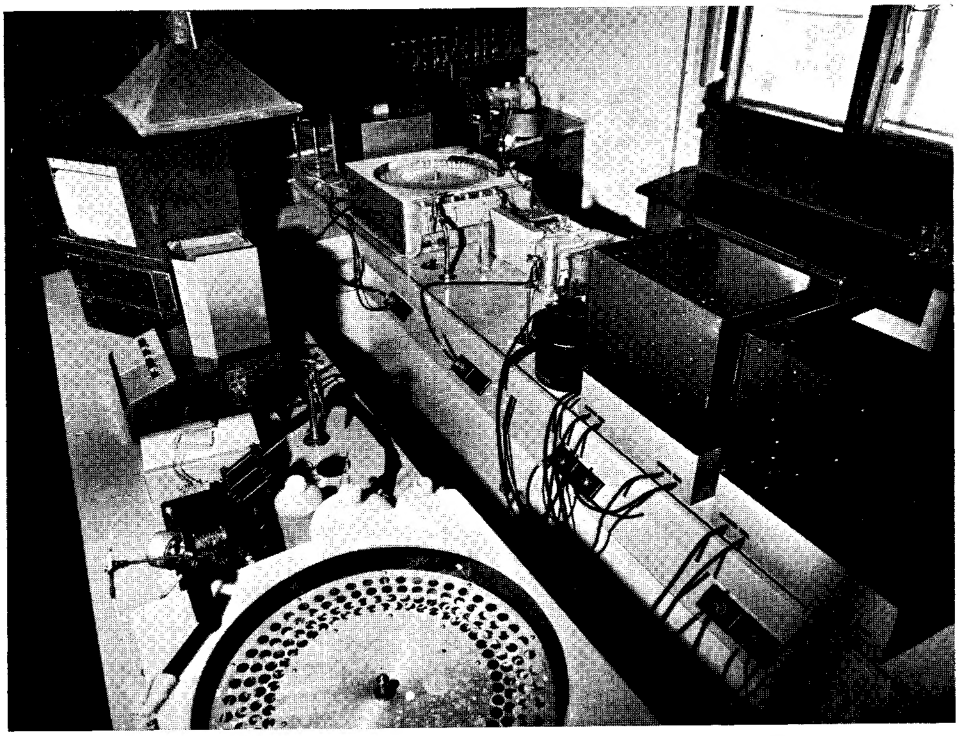

FIGURE 23 *Special arrangement of benches, to provide easy access to backs of instruments, and keep the bench top free of electricity cables; CSIRO Cunningham Laboratory, Brisbane, Qld.*

In the laboratory illustrated, a space of 2 ft between two rows of benches acts as a service corridor in miniature; it provides easy access to the backs of the instruments and it keeps the bench top clear of power cables and tubing. The reagent bottles are grouped at one end of the unit, below bench level; they stand in a polythene tray and they are connected to the auto-analysers by tygon tubing with two-way teflon taps; as well as helping to keep the bench top clear, this also eliminates some toxicity problems.